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Global Tomato Production: Price Sensitivity and Policy Impact in Mexico, Türkiye, and the United States

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Abstract: Tomato, a vital subtropical vegetable crop, is in demand globally but is produced in limited regions. Recently, its supply has become increasingly influenced by internal and external production factors. This study analyzed the impact of price fluctuations and evolving agricultural support schemes on tomato production in three key producers: Mexico, Türkiye, and the United States, which play significant roles in the global market with specialized production and trade. Using time-series price response data from 1991 to 2022, the research examined market prices, government support policies, and international trade agreements. Long-term price effects were similar in Türkiye and the USA but negligible in Mexico. Short-term price differences were positive across all countries, with the strongest impact in the USA. Financial support programs increased supplies in alignment with time-based effects. Deviations from long-term equilibrium were corrected in all countries, with Türkiye showing the fastest recovery. The results suggest that decoupled supports positively influence supply and merit further promotion.

Keywords: tomato; supply; price; supports; vector error correction

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1. Introduction

The demand for agricultural products has historically been constrained by available production facilities and inputs. However, technological advancements and improved transportation capacities have led to induced demand and rising supplies consequently. Furthermore, increasing global awareness of previously unfamiliar products, including horticultural products, which were once limited to tropical or subtropical regions, has led to the development of new markets. These sorts of horticultural crops are now key consumer products, contributing significantly to economies and export potential in producing countries.

The relationship between supply responsiveness and time dependency has been a focal point in economic literature. Extensive research has examined price-responsive products and the impact of price trends on producers' future decisions. Some product lines are easily substituted for others that are more price-efficient, reflecting market adaptability. Decisions on cultivating specific crops are tied to market demand and influenced by both internal and external factors that affect aggregate supplies. The price of the product itself is often the most critical internal factor for agricultural commodities. Non-price factors, such as producer and consumer characteristics and policy changes or macroeconomic indicators, also influence these processes. Measuring the effects of these factors is crucial for policymakers and for guiding individual stakeholders through dissemination activities.

This research focuses on measuring and evaluating price and non-price factors affecting tomato supplies in a comparative way in different settings, taking periodic effects

into consideration. Tomatoes, as a subtropical vegetable, have emerged as an essential consumer product worldwide. A key crop within the Solanaceae family, tomatoes are extensively cultivated in temperate regions, prized for their culinary versatility and economic significance. Originating in southern Mexico around 500 BC, tomatoes were introduced to Europe in the 16th century, particularly in Spain and Italy. Over time, they have become indispensable in global cuisine, with production increasingly influenced by price dynamics and agricultural policies. Due to climatic requirements, mass production of tomatoes remains limited to specific regions even under controlled environments. This research aims to assess the aggregate price responsiveness of tomato supplies in countries that have market importance, providing insights into macroeconomic policy development in both the short and long term.

This study focuses on three major producers: Mexico, the USA, and Türkiye. Mexico, as the tomato's origin and a major global exporter, is a key focus. The USA, producing nearly one-third of global tomato supplies, particularly in California and Florida, is the second subject of analysis. Türkiye, with its extensive production experience and prominent market share in Europe and the Middle East, forms the third case.

This research employs a time-series analysis approach to evaluate the impact of price and non-price factors. The special focus of this study is on the effects of different support schemes employed and policy changes in these countries in a comparative way. It was considered that evaluation of the market dynamics in these countries would provide insights for future policies. The main expectation for supplies of normal products is to have positive price responsiveness, which is also bound to the available resources. Additionally, public or private, mostly in the form of contract farming, supports are also expected to stimulate supplies.

The importance of tomato production and the significant supporting systems incorporated in tomato production in three countries were presented in the following section. After this, the time-series methodology incorporated was reminded briefly. The paper followed with a presentation of findings and implications and conclusions drawn.

2. Changing Tomato Production and Supporting Schemes in Türkiye, the USA, and Mexico

The context for the analysis was defined following an assessment of production and efficiency figures for Türkiye, the USA, and Mexico.

For Türkiye, available tomato production data dates to 1961 due to national databases. Total production rose from 1.1 million tons to 13 million tons, a tenfold increase from 1961 to 2022. The change in production and prices between 1991 and 2022 was indicated in Figure 1 based on the FAO data.

The amount seemed to double from 6 million to 13 million tons from 1991 to 2022. During this period, yield per hectare grew steadily, almost quadrupling from 19 tons to 81 tons. The average land utilized for production over 32 years was 186,230 hectares. The production lands have been fluctuating, and its highest level was measured in 1999 with 213,255 hectares. The yield per hectare increased consistently from 35.2 tons to 81.9 tons. The average yield over the period was 54 tons, with productivity surpassing this average starting in 2007.

The quantity grew at an average rate of 2.68%. Meanwhile, the price fluctuated between USD 181 and USD 662.7 per ton, with an average growth rate of 3.62%. The highest price was recorded in 2010. Factors contributing to price fluctuations included supply chain disruptions, supply deficits due to surging demand, volatile energy and input prices, and currency fluctuations, particularly in Türkiye. Global inflationary trends and COVID-19-related supply reductions were also significant contributors to sudden price

changes [1]. A sharp 66% price increase from 2021 to 2022 was attributed to the easing of pandemic-related restrictions [2].

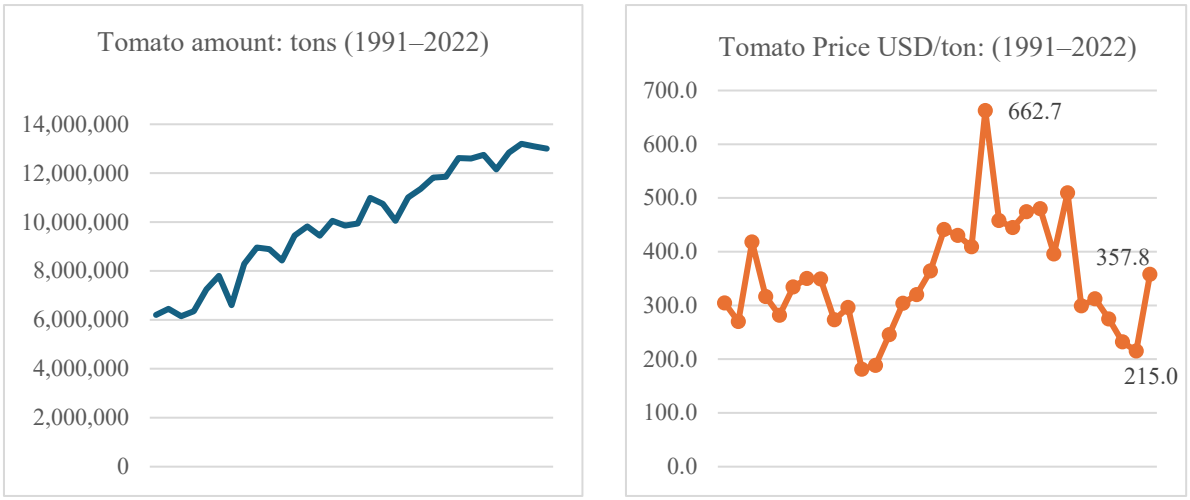


Figure 1. Tomato production (tones) and tomato prices (USD/ton) for Türkiye (1991–2022).

During the analysis period, two major policy changes were observed in Türkiye. The first was the introduction of insurance discounts for horticultural producers under the Agriculture Law enacted in 2006. The second was the adoption of Good Agricultural Practices, supported by GlobalGap after 2010. This change was reflected in subsidies for pesticides and plant nutrition in the field and greenhouse vegetable production. How did Turkish horticultural production supports evolve during this period? The support provided per unit of land, introduced in 2011, showed fluctuations over time as demonstrated in Figure 2.

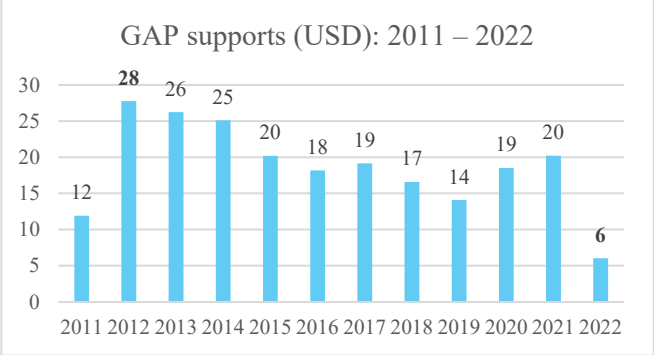


Figure 2. GAP supports to Tomato Production (tones) in Türkiye (2011–2022).

While the value of GAP supports remained consistent in national currency since the late 2010s, it fluctuated in price (USD) and depreciated over time. This USD-adjusted fluctuation was influenced by macroeconomic factors such as the depreciation of the Turkish Lira and inflation [3].

Next, changes in the USA market were analyzed. As one of the world's leading producers, the USA accounts for approximately 35% of the global market. As can be seen from Figure 2, production volumes increased from about 5 million tons in the 1960s to an average of 10 million tons by the 1990s. Supplies fluctuated around 10 million tons in the last three decades, as illustrated in the figure below.

As can be seen in Figure 3, the highest production level in the USA was nearly 16 million tons in 2014. Subsequent fluctuations and declining production levels can be

linked to changing tomato trade dynamics, with nearly one-third of domestically consumed tomatoes being imported from Mexico [4]. These fluctuations persisted, and the cultivated area decreased from nearly 200,000 hectares to 106,000 hectares. Correspondingly, yield per hectare increased 3.75 times, rising from 25.45 to 95.54 tons. Rising prices became notable, peaking at USD 1259 per ton in 2020 due to reduced supplies, as illustrated in the graphical analysis. This trend underscores the inverse relationship between quantity and prices, which was analyzed alongside specific supporting schemes.

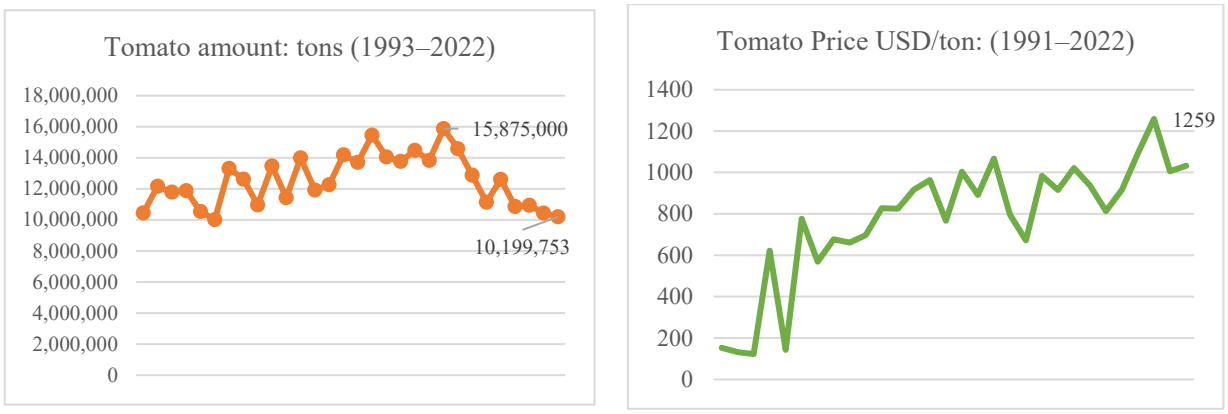


Figure 3. Tomato production (tones) and tomato price (USD/ton) for the USA (1993–2022).

The federal government played a significant role in shaping policies, becoming a founding member of NAFTA in 1994, implementing GAP/GHP measures in 2002, and introducing the Food Safety Modernization Act (FSMA) in 2011. The FSMA program included three key support measures: the Federal Crop Insurance Program, subsidies, and indemnities [5].

The change in the amount allocated in the scope of FSMA was demonstrated below in Figure 4.

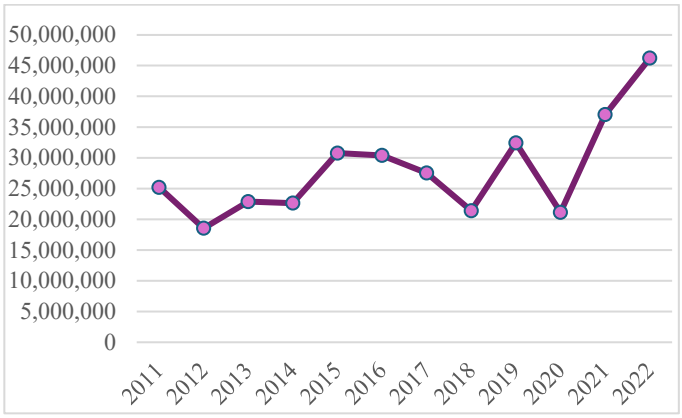


Figure 4. Total federal supports for horticultural production (2011–2022).

The allocated amount for support fluctuated around USD 25 million. However, it increased to USD 37 million in 2021 and USD 46 million in 2022, primarily to address the recovery from the COVID-19 pandemic. These supports also included funding for sanitary enforcement measures, particularly in food manufacturing, as mandated by the authority [6].

Mexico, the third key player in the international tomato market, is the birthplace of tomato domestication and remains its most prominent exporter. Its primary export markets are in North America, with the USA and Canada occupying the top two positions [7]. Japan

ranks as the next largest importer, followed by markets in Central America and the Middle East. According to the Secretariat of Agricultural and Rural Development (SADER), Mexico generated nearly USD 3 billion in revenue from tomato exports in 2023 [8]. Furthermore, tomatoes rank among the top five export products of the country. Production figures are demonstrated below.

Production in Mexico has increased in response to growing export demand. As can be seen in Figure 5, between 1991 and 2022, output doubled from 2.1 to 4.5 million tons, a significant rise compared to the 470,527 tons recorded in 1961, according to FAO data. Over the past two decades, the cultivation area has been shrinking, but yield per hectare has improved nearly sevenfold, rising from 6.83 tons in 1961 to 46.4 tons in 2022. Price per ton has fluctuated during the observation period, a trend attributed to the shift from open-field to protected cultivation systems aimed at enhancing climate resilience, as nationally promoted [9]. Additionally, importers increasingly demand higher quality, including better flavor, firmness, color, and aroma [10].

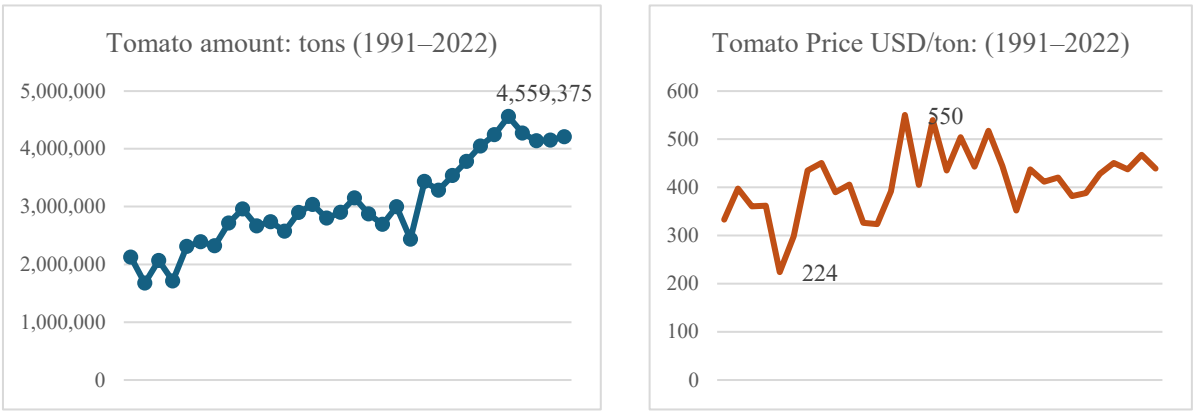


Figure 5. Tomato production (tones) and tomato price (USD/ton) for Mexico (1991–2022).

To protect domestic producers, the United States has imposed anti-dumping measures on certain Mexican vegetable exports, particularly fresh tomatoes. These measures prevent Mexican producers from selling tomatoes in the USA at prices below fair market value, which could harm American growers. In 1996, a suspension agreement was signed to establish a minimum export price for Mexican tomatoes, safeguarding USA producers [11]. The agreement has been renewed multiple times—in 2002, 2008, 2013, and most recently in 2019, as reported by the USA Department of Commerce [12]. Producers in Florida and California advocate for the continuation of anti-dumping measures to sustain domestic production [13].

Recognizing its dependency on tomato exports, the Mexican government actively supports tomato production. Since 2001, subsidies for protected cultivation have aimed to meet importers' quality demands and expand protected farming areas. The Agri-Food Productivity and Competitiveness Program (AFPCP), managed by SADER (the Ministry of Agriculture and Rural Development), supports farmers through production, harvest, post-harvest, and marketing stages [7]. From 2006 to 2022, SADER allocated USD 4.7 billion annually, while PEC (Productivity and Economic Competitiveness) support averaged USD 19 billion per year, according to USDA records [14].

3. Materials and Methods

In estimation of quantity produced, supply response methodology was used, focusing on measurement of the price impact. In implementation, the equilibrium of input composition and related amounts of production could be studied with efficiency measures. Another

approach, which is the one being used in this research, relies on estimation of expectations and factors affecting the supply. To estimate the quantity produced, a supply response methodology was employed, focusing on measurement of price impact. In practice, input composition and production efficiency could be analyzed; however, this research prioritizes estimating expectations and factors influencing supply. The method includes the price of the product as a quantitative variable while incorporating non-price factors into the equation. This approach is commonly referred to as Nerlovian time-series estimation of supply [15]. The initial form of the equation is as follows:

$$Q_t = \beta_0 + \beta_1 P_t + \beta_2 Z_t \quad (1)$$

Here, the retrieved amount of output for time t (Q_t) is estimated against price (P_t) and non-price (Z_t) factors with relevance to time t.

Non-price factors include variables such as exchange rates, taxes, inputs like land or labor, and institutional or policy changes. In modeling agricultural production, it is critical to account for the fact that production decisions cannot be revised immediately based on current prices or socio-economic indicators. The Nerlovian approach, assuming at least a one-period lag, progressed in time [16]. The methodology for estimating production elasticities incorporates lagged values for quantity and price.

However, while lag periods can be approximated, reliance on non-stationary data can lead to overestimated relationships [17]. Establishment of causal relationships from non-linear level data is the main stance of time-series analysis. The aim is to disaggregate time effects via modification or adjustment of especially the quantitative variables that take place in the supply function. To address this, the Error Correction Methodology (ECM) is applied to determine time dependency. This involves testing data stationarity and cointegration [18] while disaggregating short- and long-term relationships [19].

The analyses covered a timespan between 1991 and 2022 for Türkiye and Mexico, and between 1993 and 2022 for the USA. The reason for selecting this limited time span is the availability of comparable price data. While the amount and field of production date to 1961, the comparable and reliable price data can be collected at the earliest in the beginning of the 1990s in FAO datasets.

Main explanatory variables of the analyses include price in USD per ton (USD/ton) and land utilized for production in hectares. Building on this methodological framework, additional explanatory variables, including information on supports/subsidies, were disaggregated for the three targeted countries in Table 1.

Table 1. Explanatory variables representing support levels for Türkiye, USA and Mexico.

Explanatory Variables for Türkiye	Explanatory Variables for the USA	Explanatory Variables for Mexico
• GAP_t = Good Agricultural Practices supports (USD) (2011–2022).	• INS_t = Insurance supports (USD) for the FSMA program (2011–) • SB_t = Horticultural subsidies (USD) for the FSMA program (2011–) • IND_t = Indemnity supports (USD) for the FSMA program after 2011. • Total S_t = Total supports (USD) for the FSMA program after 2011 (alternative financial indicator).	• $SADER_t$ = Supports (USD) by the Secretariat of Agriculture and Rural Development after (2006–). • PEC_t = Horticultural subsidies (USD) from the Agri-Food Productivity and Competitiveness Program (2011–).

The variables representing supports/subsidies provided to the producers or the market representatives are expected to affect supplies in a positive direction. Nevertheless, the research also aimed to understand whether this effect is valid in the short and long term. In addition to financial data, dummy variables representing support provisions for each country were incorporated into the estimation process. GAP provisions were dated to 2002 for the USA and 2011 for Türkiye. The agricultural insurance program under Türkiye's Agriculture Law began in 2006 and continues to date. FSMA supports in the USA started in 2011. For Mexico, SADER and PEC supports were allocated starting in 2006 and 2011, respectively. The establishment of NAFTA in 1994 was included as an additional variable for the USA and Mexico, and a trend variable was applied where necessary. The analyses were performed using Python with Anaconda libraries.

4. Results

4.1. Impact of Policy Changes on Tomato Supplies in Türkiye

The relationship between supply and price was evaluated alongside the inclusion of GAP support values. To establish a comprehensive relationship, additional descriptive variables reflecting policy changes were incorporated into the model as outlined earlier. Dummy variables were used to indicate the implementation of the modified agricultural insurance system in 2006 (TARSIM) and the introduction of GAP supports in 2010. Subsidies for pesticides and plant nutrition per unit of land were also considered as supplementary factors, but only after establishing concrete relationships.

The initial objective was to evaluate the feasibility of the analysis. Thus, the normality of quantitative variables was tested and interpreted using two significant normality tests, Shapiro–Wilk [20] and D'Agostino K-squared [21]. Both tests have the assumption of normality. Statistical results indicated that, at a 95% significance level, neither production quantity nor price deviated significantly from normality as demonstrated in Table 2. These results provide strong evidence of suitability for further analysis.

Table 2. Normality of the main variables for Türkiye.

Variable	Shapiro–Wilk Statistic	D'Agostino K-Squared Statistic
Q	0.93 (0.05)	4.64 (0.1)
A	0.97 (0.53)	1.43 (0.49)
P	0.96 (0.2)	5.71 (0.06)

Departing from average normality, the relationships between variables were examined. A priori, one would expect a default correlation between the quantity to be estimated and the relevant explanatory variables. However, the correlation between some explanatory variables was not strongly supported. The data showed a negative correlation between quantity and production area, while a positive correlation was observed with price. The weak significance of the relationship with production area can be attributed to increasing yields driven by advancements in production capabilities rather than an expansion in cultivated land.

Following this assessment, the relationship between price, production area, and quantity produced was further investigated using multiple linear regression within a time-series framework. The results of the initial level estimation take place in the below Table 3.

The positive relationship with price and negative relationship with production area were evident from the parameter estimates. However, both the individual and joint significance levels of the parameters were notably low. With the mean dependent variable (MDV) around 10 million tons, the constant accounted for over 90% of the variation, while the explanatory power of the model was just 3%. This raised concerns about multicollinear-

ity among the variables, as the Durbin–Watson statistics also indicated strong negative autocorrelation of errors. To address this, stationarity of the variables was tested using the Augmented Dickey–Fuller (ADF) test [18]. The ADF results confirmed that none of the variables were stationary at their levels, with statistics of −1.39 (0.59) for quantity produced, −1.36 (0.60) for production area, and −2.07 (0.26) for price per ton. Also, *p*-values in parentheses are far above 0.10 indicating rather low significance.

Table 3. Static relationship between variables for Türkiye.

Factor	Estimate	*p*-Value		
constant	9,285,387	0.1	**F-statistic (p)**	0.43 (0.65)
P	3635.94	0.38	**R^2**	0.03
A	−3	0.91	**Durbin–Watson**	0.14

Given the negative correlation between quantity and production area, the latter was removed from the equation. However, the results still showed the same issues: multicollinearity, an insignificant F-statistic (0.88), low explanatory power (3%), and continued negative autocorrelation (Durbin–Watson statistic = 0.13). This prompted researchers to focus on achieving stationarity in the relationship. Statistical strength and economic efficiency were pursued through approaches assuming the relationship to be difference-stationary [22,23], lag-stationary, trend-stationary [24], or a combination thereof, reflecting the data's characteristics. Reducing multicollinearity indicated increasing stationarity [19,25]. Consequently, the long-term relationship explaining fluctuations in tomato supply was established by incorporating previous supply levels and lagged prices and results were shown in Table 4.

Table 4. Long-term tomato supply estimates for Türkiye.

Factor	Estimate	t-Statistic (p)	VIF		
constant	5,006,421.55	3.89 (0.00) ***		**R^2**	0.96
Q (−1)	0.17	0.85 (0.40)		**F-statistic (p)**	142.03 (0.00) ***
P (−1)	35,882	0.37 (0.71)	1.26	**Durbin–Watson**	1.91
GAP	5783.25	0.40 (0.69)	2.57		
trend	189,622.55	3.64 (0.00) ***			

*** Statistically significant at 99%.

With reduced autocorrelation (as indicated by an improved Durbin–Watson statistic) and multicollinearity eliminated with variance inflation factor (VIF) values below 5 [26], the relationship became interpretable following lag transformation and inclusion of a trend variable.

The findings suggest that 96% of the variation in production was explained by the lagged quantitative data. However, half of the average 10 million tons of production was unrelated to any factors, while supplies increased by approximately 190,000 tons per year. Additionally, 17% of the previous year's production contributed to current supplies, and a unit increase in the previous year's price per ton resulted in a production rise of 358 tons.

In moving from this long-term interpretation, deviations from equilibrium were examined for the short term. The error terms of the long-term relationship were assessed, with test results confirming their normal distribution: Shapiro–Wilk statistic = 0.958 (p = 0.26) and D'Agostino K^2 statistic = 2.14 (p = 0.34).

Short-term relationships were then estimated by differencing the long-term data and assessing the effects of disturbances using a lagged Error Correction Model (ECM) [19]. These findings demonstrated in Table 5 explained 43% of the deviation. The average

inter-period difference in tomato supplies was 284,152.80 tons, with 54% of the inter-period variance occurring independent of the included estimators.

Table 5. Short-term tomato supply estimates for Türkiye.

Factor	Estimate		
constant	154,951.16	**R^2**	0.43
ΔQ (−1)	0.35	**F-statistic (p)**	4.76 (0.01) ***
ΔP (−1)	543.00	**Durbin–Watson**	1.84
ΔGAP	6984.72		
ECM (−1)	−0.95 ***		

*** Statistically significant at 99%.

The estimate of the differenced quantity indicates that 35% of the variation is explained by changes in the previous period. However, the price difference influences quantity by only 543 tons per period, suggesting a relatively low impact given the minor price changes per period. Additionally, an increase in GAP supports after 2010 contributes to a supply rise of 7000 tons annually, accounting for 162,000 tons of annual growth independent of other factors.

The long-term convergence to equilibrium was confirmed with a −0.95 estimate for the lagged residuals of the long-term model. This significant negative coefficient indicates a strong recovery within one year, despite fluctuations in other factors, highlighting stable market conditions for tomatoes in Türkiye. The rapid adjustment speed substantially contributes to inter-period or annual fluctuations in tomato supplies. This is further supported by the joint significance of the short-term model, reflected in an F-statistic of 4.76 and a Durbin–Watson statistic of 1.84.

4.2. Impact of Policy Changes on Tomato Supplies in the USA

To set the stage for the analysis, the data structures were thoroughly examined. The quantitative explanatory variables, including land area, price per ton, and FSMA program supports, were found to be non-normal, while only the quantity of production exhibited a normal distribution. Correlation analysis revealed that the quantity produced had a positive relationship with both the field of production and price per ton. Conversely, a negative correlation was observed between land and price, suggesting that focusing on only one factor might yield statistically and economically meaningful findings. Nonetheless, the initial static relationship included both variables for a comprehensive evaluation as summarized in Table 6.

Table 6. Static relationship between variables for the USA.

Factor	Estimate	*p*-Value		
constant	1,840,542.86	0.48	**F-statistic (p)**	8.71 (0.00) ***
P	3755.98	0.00	**R^2**	0.39
A	49.14	0.00	**Durbin–Watson**	1.48

*** Statistically significant at 99%.

The variables could be included in the equation simultaneously to examine the impacts of supportive actions. However, before proceeding, the stationarity levels of the main variables were tested. Additionally, support provided in USD across three dimensions—insurance (INS), subsidies (SB), and indemnities (IND)—was analyzed for unit roots. Among these, only the price variable was stationary at the 90% confidence level. Since stationarity is essential for time-series measures, the variables were transformed, and

their time-dependency was reassessed. Based on the ADF test results, the variables were determined to be differentially stationary, as shown in Table 7.

Table 7. Stationarity testing of quantitative variables for the USA.

Variable	ADF Statistic	*p*-Value	Variable	ADF Statistic	*p*-Value
Q	−1.43	0.57	**INS**	−0.21	0.94
A	−0.70	0.85	**SB**	−0.30	0.93
P	−2.74	0.07 *	**IND**	1.44	1.00
Q (−1)	−2.86	0.05 **	**INS (−1)**	−0.49	0.89
A (−1)	1.22	1.00	**SB (−1)**	−0.53	0.89
P (−1)	−1.64	0.46	**IND (−1)**	0.22	0.97
ΔQ	−8.99	0.00 ***	**ΔINS**	−4.96	0.00 ***
ΔA	−14.07	0.00 ***	**ΔSB**	−5.09	0.00 ***
ΔP	−1.68	0.44	**ΔIND**	−10.56	0.00 ***

* Statistically significant at 90%, ** significant at 95%, *** significant at 99%.

Following these diagnostics, the long-term relationship for tomato supplies in the USA was estimated. While individual financial supports appeared statistically insignificant, the total value of FSMA program supports was treated as an influential factor. Additionally, period dummies were included as estimators to account for the introduction of GAP supports in 2002 and the FSMA program in 2011. The resulting long-term relationship explains 46% of the variation in the quantity supplied during the analyzed period as demonstrated in Table 8. The constant estimate represents 75% of the mean supply, which was 12.5 million tons for the period in question.

Table 8. Long-term tomato supply estimates for the USA.

Factor	Estimate	t-Statistic (p)	VIF		
constant	9,527,364.72	8.45 (0.00) ***	21.78	**R^2**	0.46
Q1	0.18	1.75 (0.09) *	1.40	**F-statistic (p)**	4.13 (0.01) ***
P1	319.63	0.23 (0.82)	3.27	**Durbin–Watson**	1.61
GAP	1,207,174.22	1.35 (0.19)	2.86		
FSMA	2,900,790.62	1.86 (0.07) *	9.97		
Total S	−0.13	−2.48 (0.02) **	10.11		

* Statistically significant at 90%, ** significant at 95%, *** significant at 99%.

The trend analysis revealed that subsidies affected supplies positively, while insurance supports and indemnities had a negative effect. However, due to multicollinearity concerns, the total sum of supports was used instead, which produced a negative estimate. This result reflects the limited share of direct subsidies, accounting for only 20–25% of total support. Despite multicollinearity, the model remains interpretable, supported by acceptable Durbin–Watson and VIF values. The previous year's supplies contributed 18% to current production, while a unit increase in the previous year's price per ton raised tomato production by 319 tons. The availability of GAP supports and total FSMA programs added 1.2 and 2.9 million tons, respectively, to annual average supplies since their introduction in 2002 and 2011. By 2011, the constant representing estimated average production rose to 13.56 million tons, exceeding the mean dependent variable, despite the significantly negative effect of total FSMA supports.

From this long-term relationship, the error terms were analyzed for their distribution characteristics. Variations were found to be normally distributed, with Shapiro–Wilk (0.96, $p = 0.39$) and D'Agostino's K^2 (0.74, $p = 0.69$) statistics confirming normality. Additionally, the disturbances were stationary at level, as indicated by an ADF statistic of −4.36 at the 95% confidence interval. Consequently, a short-term relationship was estimated, focusing on correcting annual differences and findings were demonstrated in the below Table 9.

Table 9. Short-term tomato supply estimates for the USA.

Factor	Estimate		
constant	−27,179.23	**R^2**	0.38
ΔQ (−1)	0.11	**F-statistic (p)**	3.65 (0.02) **
ΔP (−1)	1606.75	**Durbin–Watson**	2.16
ΔTotal S. (−1)	−0.05		
ECM (−1)	−0.70 ***		

** Statistically significant at 95%, *** significant at 99%.

The primary significance of the short-term equilibrium lies in the negative constant estimate. Due to fluctuating tomato supplies, which have shown a declining trend over the past decade, the average annual difference is −8.3 million tons, as illustrated in Figure 3. Consequently, the remaining factors exhibit a stronger recovery effect, excluding the change in total supports, as anticipated. The significant speed of adjustment suggests a 70% return to the average equilibrium within one year, indicating a relatively stable tomato market despite its downward trend. This declining tendency is further evident in the 5-year forecasts derived from long-term estimates, as shown in Table 10 below.

Table 10. Forecasted tomato supplies for the USA (2023–2027).

Year	Forecasted Q
2023	9,262,127
2024	8,671,995
2025	8,081,864
2026	7,491,733
2027	6,901,601

4.3. Impact of Policy Changes on Tomato Supplies in Mexico

The financial aids to Mexico were measured under two categories in this research. These are SADER provisions and the Special Concurrent Program for Sustainable Rural Development (PEC) since 2006. Alongside quantitative variables, the effects of Mexico's founding membership in NAFTA and the timing of suspension agreements were also evaluated.

The average production quantity was 3 million tons, fluctuating in response to macroeconomic challenges and policy interventions. The average price per ton was USD 410.9. Before analyzing relationships, the normality of key indicators was assessed. Both supply figures and prices, despite their fluctuations, exhibited normality, while the field of production showed limited variation and was non-normal. Correlation analysis revealed that price had a positive impact on quantity, while non-varying land had a negative effect. Financial supports significantly and positively influenced supplies.

Subsequent investigation of the static relationship showed initial findings marked by strong negative multicollinearity and low explanatory power, explaining just 27% of the variation. The statistical results of this initial estimation take place in Table 11.

Table 11. Static relationship between variables for Mexico.

Factor	Estimate	*p*-Value		
constant	4,106,890	0.00 ***	**F-statistic (p)**	5.39 (0.01)
P	3,539,863	0.06 *	**R^2**	0.27
A	−24.22	0.01 **	**Durbin–Watson**	0.74

* Statistically significant at 90%, ** significant at 95%, *** significant at 99%.

Multicollinearity can be addressed through variable modification. Before proceeding, the stationarity of the variables, including SADER and PEC support values, was evaluated.

Non-stationary level variables were found to become stationary at the first difference looking at *p* values of 0.00 representing 99%,while only price achieved stationarity in its lagged form as can be seen in Table 12.

Table 12. Stationarity testing of lags and differences in quantitative variables for Mexico.

Variable	ADF Statistic	p	Variable	ADF	p	Variable	ADF	p
Q	−0.86	0.80	**Q (−1)**	−0.82	0.81	**ΔQ**	−9.33	0.00
A	−0.97	0.76	**A (−1)**	−0.91	0.79	**ΔA**	−8.39	0.00
P	−3.75	0.00	**P (−1)**	**−3.65**	**0.00**	**ΔP**	−8.39	0.00
SADER	−1.26	0.65	**SADER (−1)**	−1.24	0.66	**ΔSADER**	−4.54	0.00
PEC	−0.92	0.78	**PEC (−1)**	−0.95	0.77	**ΔPEC**	−4.57	0.00

Correlations among variables were re-examined for period lags. On the level, the quantity produced was correlated with the field of production and total production, but the correlation with the previous price level was insignificant. Cointegration for a one-period lag was detected, consistent with previous analyses. Current production was regressed on the previous production amount, land, and price level, but this resulted in overestimation, as none of the parameters were significant despite overall significance measured by the F-statistic, and weak multicollinearity was indicated by a Durbin–Watson statistic of 2.84.

Instead of using dummy variables for NAFTA membership, the long-term relationship was modeled using a trend variable to eliminate multicollinearity. The resulting relationship is summarized in Table 13.

Table 13. Long-term tomato supply estimates for Mexico.

Factor	Estimate	t-Statistic (p)		
constant	1,309,012.92	3.89 (0.00) ***	**F-statistic (p)**	53.23 (0.00) ***
Q (−1)	0.18	0.88 (0.39)	**R^2**	0.89
SADER	15,461.23	0.16 (0.87)	**Durbin–Watson**	1.86
PEC	−28,519.47	−0.86 (0.40)		
trend	88,286.37	3.30 (0.00) ***		

*** significant at 99%.

It was observed that 1.3 million tons, accounting for 40% of the 3 million tons of average supply, were unrelated to either previous production levels or supporting measures. However, 18% of the supply was influenced by the previous year's production quantity. The annual supply showed a time-dependent increase of 88,286 tons. The impact of supports varied. Efficiency-related funding positively influenced supply, while regional development funds had a negative effect. With this trend-stationary assessment, multicollinearity issues were resolved.

Shifting focus from long-term relationships, the error terms were analyzed to interpret short-term equilibrium variations. These variations were confirmed as normal, with a Shapiro–Wilk statistic of 0.96 ($p = 0.39$) and a D'Agostino K^2 statistic of 2.14 ($p = 0.69$). Additionally, the error terms were found stationary with an ADF statistic of −5.02 ($p = 0.00$), allowing their use for short-term explanations. The short-term equilibrium was demonstrated in Table 14.

In the short term, supply differentials and changes in rural development funding negatively impacted averages. Unlike in other countries, changes in the previous year's supply contributed negatively to current supply variations.

Table 14. Short-term tomato supply estimates for Mexico.

Factor	Estimate		
constant	141,614.70 ***	**F-statistic (p)**	3.49 (0.02) **
ΔQ (−1)	−0.10	**R^2**	0.42
ΔP	380.17		
ΔSADER	246,519.02	**Durbin–Watson**	1.97
ΔPEC	−114,294.30 *		
ECM (−1)	−0.77 **		

* Statistically significant at 90%, ** significant at 95%, *** significant at 99%.

The long-term appreciation has been rapid, with price differences positively influencing the equilibrium. Depending on price fluctuations, the periodic effect could be either positive or negative. Changes in support measures had a similar impact. Convergence to long-term equilibrium was again observed through the negative estimate of the error term. After completing these estimations, it was deemed valuable to compare and evaluate the results across the three significant countries.

5. Comparison, Inferences, and Policy Implications

5.1. Key Findings and Comparative Insights

The research findings provide comparable information on **three dimensions**. The potential to increase production, the impact of price and time dependency, or traditional characteristics of tomato cultivation were noted and explained below.

Firstly, the propensity to increase tomato production varies across Türkiye, the USA, and Mexico, yet dependency on previous supplies and price differences exhibits a consistent pattern.

Secondly, the rising per-unit price contributes approximately 300–400 tons to the following year's supply in all three countries in the long term. This limited positive impact underscores the relative rigidity of horticultural producers, who are less inclined to shift between crops due to the high initial investment and specialized skills required. This consistency mirrors findings in resilience studies, which demonstrate that producers maintain output levels even during market shocks like COVID-19, as observed in both the USA and China [27]. Tomatoes, which rank as the second most important export crop after avocados, are deeply embedded in Mexico's agricultural economy, leaving producers with little flexibility to pivot to alternative crops [28]. The effects of prices in the targeted countries are different in the long term.

In Türkiye and the USA, the long-term impact of price on supply is positive, indicating that higher prices provide an incentive to maintain or increase production.

Some recent studies indicated similar price effects. Researchers made ARDL estimation of tomato supplies in Cameroon for 1994 and 2018 and found out that producers are responsive to price. The effect in the short term was higher with a price elasticity of 1.8 than 0.83 in the long term [29]. In addition to increasing supplies due to rising prices, the short-term effect shows that producers would also reduce production in response to lower prices.

In Mexico, however, the price effect is negligible, likely due to the strategic importance of tomatoes as an export crop. Therefore, the responsiveness of supplies to price variation is low for all examples, which indicates price inelasticity of supplies being lower in the long term.

Price dynamics were studied monthly for onion, tomato, and potato in India with different time-series approaches between 2005 and 2021 [30]. Specifically, tomato supplies and prices were detected as volatile depending on the harvest timing. Lower supplies due to lower producer prices led to higher prices in a cyclical way to reach supply–

demand equilibrium. Chinese qualitative research on vegetable supplies inferred that rising supplies suppress prices when the demand was taken for granted without significant variation [31]. Accordingly, despite these deviations, producers maintain their dependence on tomato cropping.

Thirdly, the traditional dependency on tomato farming needs to be considered with reference to time variation.

The contribution of prior production to current supply levels remains significant in all three countries, accounting for 17–18% of current supplies in the long term.

However, short-term variations reveal divergent patterns. While previous quantity changes positively influence supplies in Türkiye and the USA, the effect in Mexico is negative. This divergence is partly attributable to Mexico's trade dynamics with the USA, where rising imports from Mexico have coincided with fluctuating and declining domestic production in the USA. Recent research on the effect of tariffs imposed by the USA on Mexican tomato demand indicated that American buyers are responsive to prices [32]. Therefore, due to reducing demand, both exports and production of tomatoes in Mexico are affected negatively. With a similar view, it was found out that Jordanian tomato supplies also reduced due to rising prices and declining export competitiveness between 2001 and 2018 [33].

5.2. Policy Implications

The findings highlight the need for tailored policy measures to address the unique challenges and opportunities faced by each country. In Türkiye, support mechanisms such as GAP subsidies have been effective in promoting tomato cultivation in the observation/recording period [34]. These supports have enabled consistent production increases, even during periods of declining prices [35]. The Turkish experience suggests that expanding decoupled support systems—those not directly tied to production levels—could enhance stability while promoting sustainable practices. Decoupled supports also provide a buffer against market fluctuations, allowing producers to make long-term investments in efficiency and quality [36].

In contrast, the USA faces challenges stemming from the unequal distribution of FSMA program funds, which have disproportionately benefited larger farms, including foreign-owned ones. The funds appeared to be disadvantageous for smaller domestic producers [37]. Addressing this imbalance by reallocating funds to smaller farms could strengthen local production and ensure more equitable access to government resources. Moreover, updating anti-dumping measures to reflect current market dynamics could help sustain domestic production, particularly in states like California and Florida, where producers face significant competition from Mexican imports.

For Mexico, NAFTA has played a pivotal role in driving tomato exports, but it has also introduced vulnerabilities in trade relationships with the USA. Mexican producers have benefited from access to the lucrative US market, but this has come at the cost of exacerbating production instability for American farmers [38]. To address these imbalances, future trade agreements should include provisions to promote fair competition and stabilize markets on both sides of the border [39]. Additionally, Mexico's policies supporting protected cultivation have the potential to enhance climate resilience and production efficiency, but their effectiveness depends on improved monitoring and alignment with measurable productivity goals.

5.3. Practical Implications

The findings also carry important practical implications for agricultural stakeholders, including policymakers, producers, and exporters. In the USA, reducing reliance on

Mexican imports while bolstering domestic production is a pressing priority. This could be achieved through targeted subsidies, support for smaller farms, and enhanced enforcement of anti-dumping laws. Such measures would not only stabilize the domestic tomato market but also ensure affordable prices for consumers.

Türkiye's success in fostering export-led growth offers valuable lessons for other countries. Through extension activities and collaborative frameworks, Türkiye has effectively integrated small producers into global supply chains. This engagement is not only limited to raw tomato marketing, as the sector provides inputs for the food industry that is also open for international trade. The contract farming between small-scale farmers with sauce factories and companies has been supporting the price expectancies of producers and quality expectations of purchasers since the 1970s [40]. This model could be adapted to other regions, particularly where small-scale farming remains prevalent. Encouraging collective action among producers can amplify export capacities and enhance the competitiveness of agricultural products in international markets.

While production seems to be lower than in the other targeted countries, Mexico is still a very significant tomato exporter. Therefore, the apparent saturation of the tomato market underscores the need for diversification. Policymakers should consider incentivizing the cultivation of complementary crops or the development of value-added processing industries to sustain rural livelihoods and mitigate the risks of over-reliance on a single commodity. Crop rotation, as well as informing farmers to shift to alternative crops such as avocados, berries, or fresh peppers, can be considered as well-respecting their rising global demand [41]. Such diversification strategies could also help address environmental concerns associated with intensive tomato cultivation, as the water demand of tomatoes is significant. Even if the producers have the tendency to continue in tomato production, they need to be informed about crop rotation and cultivation of alternative products. Especially, the export limitations of the USA toward Mexico may necessitate the importance of finding complementary products to meet domestic demand and/or finding alternative export markets.

Equitable distribution of agricultural supports remains a critical issue in all three countries. In the USA, revising eligibility criteria for subsidies to prioritize small-scale producers could make government programs more inclusive and effective. Similarly, Mexico should refine its support mechanisms to ensure that rural development funds contribute directly to measurable gains in yield and efficiency, particularly in protected–irrigated tomato production systems. Ensuring that these funds are decoupled from production volumes would further enhance their impact.

6. Conclusions

This study highlights the complexities of tomato production and supply dynamics in Türkiye, the USA, and Mexico. Despite varying trends, tomatoes remain a vital crop for both domestic and export markets in all three countries. Addressing trade imbalances, refining support mechanisms, and fostering innovation in production practices are critical for sustaining supplies. Policymakers must align reforms with broader goals of economic inclusivity, environmental sustainability, and market resilience. Even if the price appears to be a positive stimulator, its impact in the short term is higher, and its long-term effect is negligible for Mexico. Accordingly, the market in these dominant countries also needs additional supportive actions.

The research incorporates a methodological preference for keeping other factors, especially local and international demand, as ineffective on supply decisions. Under operating market conditions, demand also has significant correspondence. Therefore, in addition to supply prices and aggregate policies, consumer prices, either on a level or as

indices, shall be included in future research. As a concluding remark, it can be noted that ensuring the continued participation of small farmers, promoting collaborative approaches, and investing in research that is decoupled from production volumes are essential steps toward achieving a more stable and equitable global tomato market.

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